Crew integration and Automation Technologies

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ABSTRACT

The U.S. Army's Tank-automotive and Armaments Command (TACOM) Research Development and Engineering Center (TARDEC) Vetronics Technology Area is responsible for technology applications that support reduced crew operations in ground combat vehicles. The current program meeting this challenge is the *manned* Crew integration and Automation Test bed (CAT) Advanced technology demonstration (ATD). The CAT is the culmination of past Science and Technology Objectives (STO) that include the Vetronics Technology Test bed (i.e., the intra vehicle electronics suite STO), future scout virtual prototype ACT II effort and Crewmen's Associate Advanced Technology Demonstration.

INTRODUCTION

The goal of the CAT program is to demonstrate a multi-mission capable common two-man crew station that supports a two-crew concept. Its key technology focus areas are cognitive decision aids, an improved Soldier Machine Interface (SMI) including an indirect vision driving system and driving aids, an advanced electronic architecture design and network topology, and embedded simulation. These capabilities demonstrated by the CAT ATD will prove technology readiness leading to possible design transition and the integration of hardware and software components into FCS variants.

TARDEC's VETRONICS Technology Area is also responsible for a second ATD program known as the *unmanned* Robotic Follower (RF). The goal of RF ATD is to demonstrate a near term low risk solution to achieving an unmanned follow-on and re-supply capability. Both ATDs are supported by a single integration contractor, use the Stryker infantry carrier variant (ICV) vehicle as a test bed platform and share many common components and capabilities. Another benefit to managing both ATD efforts out of the same office is that each program supports the other. The manned CAT vehicle functions as the lead vehicle during RF testing. The RF vehicle functions as an unmanned asset during CAT workload tests.

This paper focuses on the CAT ATD and the experiments performed to demonstrate the advanced warfighter interfaces (AWI), automation, and integration technologies required by future combat vehicles. The CAT ATD is a multi-year joint effort between TARDEC, its lead system integrator - General Dynamics Land/Robotic Systems, and a number of other industry partners. All of who have contributed significantly to the success of the first set of experiments. Several key technologies and capabilities incorporated into the CAT ATD include:

- Cognitive decision aids
- Drive-by-wire controls
- Day and night operation
- Indirect vision as the primary means of driving
- Multi-modal interfaces
- Speech recognition
- Multi-function displays with touch screens
- Multi-function yoke
- Keyboard with trackball
- Embedded simulation as an enabling technology for embedded training and mission rehearsal
- Three-dimensional (3D) audio system

TECHNICAL APPROACH

During the beginning of fiscal year (FY) 2002, all ATD managers were asked to restructure their program to support the Army's Future Combat Systems (FCS) program by demonstrating technologies with near term solutions. For the CAT ATD, this meant a 13-month schedule to go from concept to prototype. To effectively meet technical program goals, engineers identified relevant technologies, long-lead items, drew upon past lessons learned and formed an integrated products team (IPT).

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Another means to meet schedule with no cost increase, the CAT ATD leveraged component technology and architectures developed by the Army research lab (ARL) and Defense Advanced Research Project Agency's (DARPA's) Demo III program. A key leveraged component technology for both the CAT and RF ATD is the autonomous mobility (AM) sensor suite.

In order to accurately define system capabilities and develop system specifications, one must first understand the problem domain. To accomplish this task, IPT membership included representatives from the Unit of Action Maneuver Battle Lab (UAMBL) Experimentation and Analysis Directorate (EAD) at Fort Knox. The role of EAD was to help in the development of militarily significant scenarios and vignettes representative of what the Army's Objective Force expected to encounter. EAD also provided the soldiers, whos' Military Operations Specialist (MOS) skills fit the effort, as crew member test subjects during the programs test period of over 2 months (6 January to 28 Mar 2003).

With the operational needs identified, development engineers began defining system requirements for both software and hardware. The IPT, including government, contractor and EAD members, worked to define an advanced multi-mission AWI supporting the fight (19K), scout (19D), and carrier (11M) MOS as well as the command and control of unmanned assets. Test engineers were then able to develop the operational and engineering evaluation test plans.

The CAT ATD system [1] was matured through an iterative approach as follows:

- Development of workload models by the Human Research and Engineering Development (HRED) Center out of the Advanced Research Laboratory (ARL) located at Aberdeen Proving Grounds (APG). IMRPINT software was utilized to model the system and human machine interfaces.

- Develop advanced Vetronics technology components for ground combat vehicles

- Integrate into Stryker vehicle and demonstrate Functionality

- Conduct field tests

- Baseline results for comparison against subsequent system developments

TECHNOLOGY DEVELOPMENT

The Crew Station designs have evolved through a number of previously mentioned technology demonstration efforts. Key enabling technologies integrated in the vehicle include decision aids and automation, AWI, embedded simulation, and advanced systems architecture.

Implemented decision aids and automation include route planning, driving (lane tracking, GPS waypoint following, and obstacle avoidance), and mission planning.

The AWI includes indirect vision driving, drive-by-wire technology, robotic mission planning and control, multi-modal interfaces, speech recognition, 3D audio, a Crewman's Associate multi-functional display concept, and panoramic displays (multiple flat panels). The AWI also includes a simulated virtual world model supporting virtual indirect vision driving, a simulated target acquisition sensor suite with automatic target recognition (ATR) system, and simulated main gun and coax-machine gun. All simulated components are accomplished via the on-board embedded simulation system (ESS).

On the move ESS includes Battlefield Visualization, Terrain Registration, Virtual Sensor Coverage, and Virtual Lethality Coverage. A goal of the ESS is the mixing of live and virtual images. This is also the program's most difficult challenge and the highest risk element for our FY06 experiments.

The advanced systems architecture is a combination of work resulting from the VTT based on the weapon systems technical architecture working group (WSTAWG) and the ARL eXperimental unmanned vehicle (XUV) program.

TECHNOLOGY INTEGRATION

Our integration approach was to procure the most promising commercial of the shelf (COTS) hardware technology and reliably integrate and package components into the two crew stations. Prior to Stryker vehicle availability, these two *common* crew stations functioned as system integration lab (SIL) resources for early hardware and software development, integration, and test.

Later we integrated the same CAT crew stations in the Stryker vehicle platform in preparation for the field tests. The goal of the field tests was to prove out technology developments using a FCS class chassis to test against the CAT ATD's exit criteria. The original plan was to layout system components so the crew stations may be placed in either a side-by-side or front-to-back configuration. Figure 1 shows the crew stations in side-by-side configuration. Due to present space constraints, we were unable to fit the crew stations in the tandem configuration for our initial set of experiments.

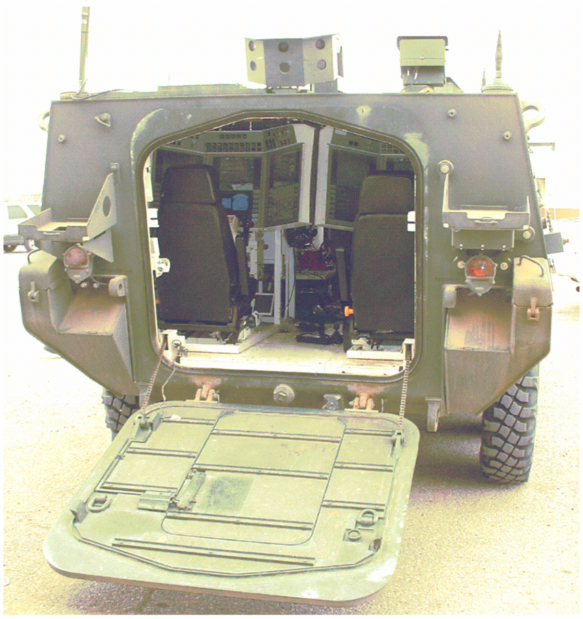

Figure 1

TESTING OVERVIEW - UNMANNED COMBAT DEMONSTRATION (UCD), ENGINEERING EVALUATIONS, AND OPERATIONAL TESTS

The purpose of these experiments and demonstrations is to show feasibility and readiness of near term technology solutions for both manned and unmanned systems within the FCS program. The two-month UCD/VTI test period conducted at Ft. Bliss, TX is separated into four phases: (1) Soldier Vehicle Training, (2) VTI CAT/RF Soldier Operational Testing, (3) UCD Maneuver and Live Fire Experiments, and (4) CAT/RF Engineering Evaluation Testing (EET).

Phase one builds off the Systems Integration Lab (SIL) soldier training that was conducted at TACOM during the first two weeks of January 2003. Active duty tankers and scouts from the Unit of Action Maneuver Battle Lab based in Ft. Knox will be trained in the actual operation of the Stryker CAT and RF platforms, crewstation, and robot control in preparation for the soldier operational testing phase.

In phase two, soldiers will conduct several mission scenarios with the CAT, RF, and XUV in military relevant situations. This operational experiment will allow us to determine workload requirements and the effects of automation technologies on the ability of the soldiers to conduct four main tasks: Infantry carrier, fight, scout, and control of unmanned assets.

In phase three, there are three (3) major objectives to be accomplished during the firing phase of UCD. The first objective is to validate the virtual findings regarding the amount of human interaction that is required to operate and control the surrogate ARVs in a tactical environment. The second objective is to confirm that the level of technology maturity for an ARV exists in order to enter the System Development and Demonstration (SDD) phase of the system acquisition process. The third objective is validation of existing ARV modeling tools by having subject matter experts (SME) analyze data collected during the demonstration and compare the results to the existing models.

In phase four, EETs of the CAT and RF, the objective is to characterize the performance of the integration and application of crewstation and robotic technology in a ground mobile platform. The EET phase will verify the technical parameters of the relevant system and subsystem components as well as the overall systems performance. Measured, demonstrated, and analyzed values will be used to characterize and verify compliance to the system specification and applicable technical design documents. These values will also be used to calculate performance metrics relevant to evaluating the performance of the system and/or subsystem.

As mentioned earlier, the goal of the CAT program is to demonstrate a multi-mission capable two-man crew station that supports a two-crew concept. Also, it proves out component technologies ready to transition and integrate into FCS.

The goal of the RF program is to utilize and develop technology for autonomous following of mounted or dismounted leader, with significant separation times and distances, and available capabilities to follow at high on-road speeds. This will allow us to demonstrate the technologies required to achieve unmanned follower capabilities for future land vehicles. RF uses a combination of GPS waypoints, terrain data obtained by sensors, Digital Terrain Elevation Data (DTED), and a digital map.

VTI VIP OPERATIONAL DEMONSTRATIONS

On March 13th, 2003 at Fort Bliss, Texas the Vetronics Technology Integration (VTI) program was successfully demonstrated to a VIP audience, which included high-ranking government and industry personnel. The VTI program is the combined contractual reference for the joint CAT and RF ATDs run by the Vetronics Technology Area. General Dynamics Land Systems (GDLS) is the prime contractor supporting both ATD programs.

The CAT and RF ATDs combined with experimental unmanned vehicles (XUV) supported the VTI Technology demonstrations, which included improved road following, cross country autonomous mobility, unmanned system teleoperation, and dismounted and mounted follower. Again, key enabling technologies required to demonstrate these abilities are an indirect vision system, autonomous mobility sensor suite, a common crew station including command and control for remote unmanned assets, task automation, global positioning system, personal data assistant, common system architecture and multiple communication systems.

The demonstration incorporated three main segments and began with the RF autonomously following a route along an improved road. The next segment incorporated the control of the RF and XUV executed in parallel from the two CAT crew stations. The first CAT operator issued the RF a series of waypoints and commanded it to autonomously drive cross-country using its autonomous mobility sensor suite while the second CAT operator remotely controlled the XUV (i.e., teleoperated) cross-county. At the same time, but in a separate location, a dismounted operator traveled cross-country autonomously followed by an XUV acting as a mule. The final segment completing the demonstration consisted of the manned CAT vehicle traveling cross-country acting as the lead vehicle with the unmanned RF performing a mounted follower capability.

One week earlier, the CAT and RF ATDs were instrumental assets supporting the Future Combat Systems (FCS) Lead Systems Integrator (LSI) Unmanned Combat Demonstration (UCD) Live Fire event. The UCD Live Fire was completed successfully when the reconnaissance surveillance and target acquisition (RSTA) XUV identified an enemy target (i.e., M113) and sent a report back to the CAT or surrogate control vehicle (CV) operator. The CV operator then commanded the surrogate-armed reconnaissance vehicle (ARV) (i.e., the RF ATD equipped with a Cougar Turret and Javelin missile system) to autonomously move to an engagement point and re-identify the target. Live video from surrogate ARV was sent back to the CV operator, who identified the target, initiated a fire sequence and remotely destroyed the enemy target with a javelin missile fired from the surrogate ARV.

FIELD TESTS / RESULTS

<u>Shake Down Tests:</u>

The "Shake Down" tests were conducted in the field at Ft. Bliss, Texas. The goals were to exercise the system in the field to make the final system calibration, and resolve any other issues critical to successfully completing field tests. Engineers from the Government, General Dynamics and its industry partners were made available for support.

<u>System Evaluation Tests [2]:</u>

System evaluation tests were conducted to baseline the performance of the system for comparison against subsequent developments. Four test subjects were used to capture sufficient crew performance data for each of the test. Specific tests included Driving from a number of positions in the vehicle, Multi-modal SMI(s) evaluation for preparing/submitting SPOT Report, and Evaluation of Speech Recognition System using a number of SPOT Reports.

The objective of the Driving tests were to demonstrate the ability of the CAT vehicle to be driven from LAV driver compartment with hatch open, LAV driver compartment with open/closed hatch, SMI crew stations using Indirect Vision Displays, and autonomously follow a planned path using its Autonomous Mobility system. The course layout consisted of three segments; 1) paved road, 2) secondary road, and 3) cross-country. The results from the driving tests were as follows; Open Hatch Driving was the best. Closed Hatch Driving was as good as the Open Hatch Driving (except when making turns where reaction time was slower as they don't see the same panoramic field of view to the left/right as open hatch). Using indirect vision driving on paved and secondary road driving was good as open hatch and closed hatch (except when making turns for the same reasons), but Cross Country was a bit more difficult which could be even more difficult had we varied the cross-country terrain.

The objective of the multi-modal SMI tests was to evaluate the use of various SMI(s) to minimize the time to complete tactical reports and/or reduce the Crew workload. Tactical reporting on cross-country using touch screen proved to be difficult. It was hard to center and press touch screen buttons while on the move and going over berms in the desert. Part of preparing SPOT report required placing the target at a specific location. To change the location of the icon the test subject had to drag it with touch. It was very easy to loose finger contact with the flat panels while on the move making. Users indicated that a better solution may to use soft numeric control to input target coordinates.

The objective of the Speech Recognition tests was to prepare and send SPOT Report using speech as input at various speeds and terrain (i.e. paved road, dirt road, and cross-country). The speech technology is still in its infancy especially for operation in dynamic environment. The performance of the speech was nominal. The user had to repeat the command twice before it recognized the command. On the positive note, the system understood natural speech better than if user was trying introduce space in between words.

HUMAN FACTORS

The test subjects were experienced Stryker Operator selected to assess and provide feedback related to usability of technologies, and hence provide credibility of the results.

Human Factors Engineers from General Dynamics, and Micro Analysis and Design developed the usability evaluations. The same engineers also setup the field tests, collected, assessed, and reported the feedback from the test subjects.

The goal of these Usability Questionnaires is to understand the user, develop good user- oriented design principles, apply them to the future SMI design, and then to make sure the enhanced interface is usable through more field tests.

Subjective Questionnaires [2]:

Typical of any engineering testing program, the collection of data is both quantitative (vehicle/operational digital data, video, audio etc) and subjective. While video and audio also fall under the category of subjective evaluation, for the CAT tests a number of subjective questionnaires were developed for the test subjects to relate their views on their individual experiences during testing while utilizing the advanced technologies. The subjects were given each questionnaire after completing respective test to ensure all the user feedback is collected while the information is still current. The list of the questionnaires follows:

- Speech Recognition Experience
- Tactical Vehicle Driving Experience
- Participant Information Questionnaire
- Speech Recognition Exit Evaluation
- Speech Recognition System Evaluation
- Input Device Exit Evaluation
- CAT Driving Evaluations
- CAT Driving Exit Evaluation
- Motion Sickness Susceptibility Questionnaire

At this time, both the quantitative and subjective data is under evaluation by our industry partners. Results are due can be obtained

CONCLUSION

The one and half weeks of CAT ATD field tests provided the much needed data (video, audio, digital) to facilitate maturation of the advanced crew technologies.

The authors have recommended that the lead integration contractor including its Human Factors Engineers hold an informal meeting with all participants to discuss lessons learned from the field test(s) and the resulting metrics.

Present and future efforts are focusing on further developing the systems that the CAT/RF effort looked at, researching new technologies and iterative testing to push the envelope of the work that has already been accomplished in order to create a system that will enhance the capabilities of the soldiers in the field.

REFERENCES

[1] Brian Novak, “Vetronics Technology Testbed”, 2001 Vehicle Technologies Symposium--Intelligent Systems for the Objective Force, May 2001.

[2] General Dynamics / Tank-Automotive RD&E Center , “VTI Engineering Evaluation Test Plan”, March 2003.